

Hard copy (HC) 1.00

Microfiche (MF) 50

N65-35234

ff 653 July 65

1. RELIABILITY PROGRAM ELEMENTS FOR SATELLITE SYSTEMS*

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One of the major missions of NASA's Goddard Space Flight

Center is the management, including the development, production

and testing of unmanned satellites to be launched into the cis-lunar space.

Since 1959 the Goddard Center has launched in excess of thirty satellite missions. In terms of useful life in orbit we have seen lifetimes for several of these in excess of one year. The excess one-year life satellites include systems such as, TIROS VI, a meteorological system, and the Orbiting Solar Observatory, a scientific satellite measuring electromagnetic radiation from the sun. Those of us who are familiar with complex electronic and electro-mechanical devices on earth, which have on the order of 5,000 to 10,000 parts, can have some feeling for the reliability problem which confronts the space system designer if we add the restraint of no maintenance capability once the device becomes operable in its intended environment.

I have come to the conclusion, and not alone, that there is no magic formula or process which guarantees reliability. The popular concept that "Reliability is Everybody's Business"

* Presented at the 20th Annual Quality Control Conference, 26 March 26, 1964, Rochester, New York

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To be presented at the Midwest Conf. of the 1964 Quality Fair, Dallas, 15-17 Oct. 1964. Submitted for publication

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does have merit, however, we have to be sure that this does not mean that everyone feels that other individuals are taking care of reliability, but that there is a vigorous and systematic effort to accomplish it. In the remarks which follow I shall outline for you what we at Goddard consider to be reliability and discuss briefly the program elements by means of which we hope to achieve it.

Let me first state in a formal way what we mean by such terms as reliability, assessment and assurance:

Reliability - The probability that a system, subsystem, component or part will perform its required functions under defined conditions at a designated time and for a specified operating period. As applicable, the word "probability" refers to a quantitative measure or to the likelihood of dependable operation.

Reliability Assessment - The procedure which provides probability estimates of the system, subsystem and components at appropriate steps of design, development and assembly in order to evaluate the likelihood of meeting established reliability goals.

Reliability Assurance Program - The technical and management functions and actions required in order to assure that a system performs in its intended manner.

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Goddard's reliability assurance program is based on a systems concept for the whole space system, namely, the launch vehicle, the spacecraft and the ground support equipment used in launching, operating and maintaining vehicles or craft in space. Also, it places primary emphasis for the flight acceptability of the system on an empirical approach - namely, demonstration of this acceptability by complete performance tests under operating conditions simulating the launch and space environment.

The major elements of the Goddard Reliability Assurance Program are the following: Reliability assessment, quality assurance, and environmental tests. The emergence of these as major elements of a Reliability Assurance Program has resulted from the experience and knowledge gained by the Center from its space programs. These programs have been almost entirely research and development efforts, with very limited production, which require a unique and specialized approach to reliability assurance.

The following represents the formal policy for Goddard:

A Reliability Assurance Program shall be a required element of each project development plan.

All space systems under Goddard management shall have a Reliability Assurance Program Plan defined in writing, the execution of which shall be the responsibility of the Project Manager. The

Reliability Assurance Program Plan shall be prepared by the Project Manager as part of his regular technical and management responsibilities.

RELIABILITY ASSURANCE PROGRAM ELEMENTS

The following represent the major elements of Goddard's reliability program:

a. Design Goals for Reliability Assurance

A definite minimum reliability goal shall be specified as part of the design requirements for a system. This will usually take the form of specified quantitative requirements that the system will perform satisfactorily for a given length of time under expected operating conditions. Requirements on subsystems, experiments and operating functions shall be specified as appropriate. For all requirements, the criteria for satisfactory performance shall be defined.

b. System Design Review for Reliability Assurance

The Center conducts formal reviews of the design for all factors affecting reliability assurance. These reviews shall be performed at times specified. The first major review shall be performed as soon as the system design concepts are firmly established, and shall include a numerical reliability assessment of the system

and establish reliability goals for the sub-systems and components. The second major review is to be performed when the more detailed design of all subsystems has been completed and is to include a failure mode analysis for all items of the system. Supplementary reviews including assessments shall be performed at the request of the Project Manager or when necessary as changes in the system or subsystem design occur and results of tests and failure reports become available.

c. Design Documents

The system shall be completely described by means of drawings, parts lists, wiring diagrams, and specifications to ensure that the prototype models are fabricated in accordance with the intentions of the design engineers, and also to serve as a permanent record of the project. Flight models shall be fabricated in accordance with the qualified design documents. These documents shall be maintained to reflect all changes in the flight hardware. The characteristics of all materials and components used shall be adequately specified. Acceptance criteria for all materials, parts, subsystems, and the complete system shall be established and stated in

the design documents. The acceptance criteria for parts and materials shall be specified by reference to standard specifications where applicable. These specifications may be NASA, military, other governmental or contractor-originated.

d. Preferred Materials

Design documents shall specify the use of preferred materials and parts. Preferred materials are defined as those which have been thoroughly qualified by tests and operational use and are known to be capable of providing reliable performance under the environmental stresses expected.

In the case of parts such as transistors, resistors, capacitors, etc., lists of preferred and approved parts produced by qualified manufacturers shall be established to assist designers in selecting parts of known reliability. Critical parts shall be manufactured under conditions of rigid quality control in accordance with specifications approved by GSFC or other sources acceptable to Goddard. Acceptance criteria for all parts shall contain electrical, mechanical and reliability requirements.

e. Preferred Practices

Preferred practices shall be utilized on all projects and should include the following:

- (1) Selection of components and parts based on reliability histories and derating curves.
- (2) Use of specified safety margins.
- (3) Simplification without loss of effectiveness.
- (4) Redundancy as required to meet reliability goals.
- (5) Application of fail-safe devices.
- (6) Consideration of degradation effects.
- (7) Use of approved design standards.
- (8) Preferred practices for methods of construction, wiring and handling of equipment.
- (9) Development of practices which decrease the possibility of human error.
- (10) At planned stages of fabrication and assembly, quality control checks to ensure that all design requirements are met.
- (11) Serialization and storage control.
- (12) An intensive effort directed toward removal of all sources of human-induced failures from the system.
- (13) Provide system characteristics for fabrication, handling and operation with maximum facility and minimum hazard to personnel and equipment.

f. Workmanship

High standards of workmanship shall be maintained by including, as a minimum, the following actions:

- (1) Setting up definite standards.
- (2) Providing the training (classroom or on-the-job) necessary to enable personnel to meet these standards.
- (3) Instituting quality controls to ensure that the standards are achieved.
- (4) Requiring all items having specified attributes to be certified as acceptable before progressing to next level of assembly.

g. Testing

A complete test program for each project shall be established and the documentation specified. It shall include, but not be limited to engineering, performance, environmental and life tests of the system and subsystems. Tests shall be performed on a complete spacecraft system including data acquisition, reduction and analysis equipment as early as possible to determine the characteristics of the integrated system. Tests shall simulate all significant stress conditions imposed on the spacecraft during handling, transportation, launch and space flight or operational

use. Prior to start of systems test a review of subsystem test experience (log books, reports, etc.) shall be conducted.

Prototype models shall be subjected to stress levels significantly higher than those normally expected; namely, 150% unless the test plan is specifically approved. All flight models shall be tested at stress levels representing the maximum that will be encountered under normal pre-flight and flight conditions.

Life tests on subsystems shall be of maximum possible duration to establish with a reasonable degree of confidence the ability of the equipment to operate without failure for the specified period of time.

h. Design Qualification and Flight Acceptance

A formal all-systems review shall be conducted following the completion of the design qualification (prototype) and flight acceptance test programs examining all test, calibration, failure analysis and correction data, and all other information pertinent to the space systems. The Project Manager shall certify the acceptability of the spacecraft system at all times.

i. Failure Reporting, Analysis and Feedback

A program of failure analysis and feedback shall include the following:

- (1) There shall be established a failure reporting system so that all failures which occur during prototype, flight systems and sub-systems testing shall be documented and analyzed to determine the cause of the failure.
- (2) A detailed history for each space system launched shall be prepared, as part of the project report, listing the cause(s) for all known failures and the estimated time after launch that the failure occurred. The corrective action recommended shall be stated so that recurrence of the failure on similar succeeding equipments shall be minimized.
- (3) A feedback program based on failure analyses shall be established and utilized to prevent repetitive failures.

j. Independent reliability contractors may be employed to assist in performing any or all of the elements enumerated above. Such independent contractors shall act solely in an advisory and

consulting capacity to the Project Manager and shall have no responsibility or authority for the Reliability Assurance Program.

In closing, let me emphasize that the above outlined program is not a panacea for all reliability problems. A program for one particular application may not be useful in another. For space systems of the kind Goddard is concerned with, the road ahead consists of increasingly more complex systems and long-life requirements consisting of 3 to 5 years of satisfactory operation in the space environment. In addition, there is no time to develop reliability growth over a long development cycle - reliability must be at its maximum with the first launch for each and every space experiment for reasons of safety, time and cost considerations.